• NEWSLINE SPECIAL INSERT •

Up Close on the NIF Project

A monthly insert on special topics at Lawrence Livermore National Laboratory. This month: the National Ignition Facility. • • • September 2003

Focus On NIF

– Ed Moses, NIF Project Manager

The Laboratory has had decades of experience with large lasers, but the National Ignition Facility makes its predecessors look small. NIF has already produced the highest laser beam energies ever, exceeding project specifications and making every member of the NIF team justifiably proud.

NIF is a tour de force from a science, technology development and engineering standpoint. The team has had to come to grips with a huge array of challenges to make NIF a reality. Working closely with industrial partners, the team found solutions for NIF's optics in rapid-growth crystals, continuous-pour glass, optical coatings and new finishing techniques that withstand NIF's extremely high energies. We have also worked with companies to develop pulsed-power electronics, innovative control systems and advanced manufacturing capabilities.

The alignment of NIF's lasers is as perfect as it can be. We have likened NIF's pointing accuracy over the 1000-foot beam-path to throwing a strike from Pac Bell Park in San Francisco to Dodger Stadium in Los Angeles. Not only that, but the huge beampath volume exceeds the cleanliness of a semiconductor factory.

Experimenters are now lining up to use NIF. In fact, they can't wait to get time on it. The first experiments have already produced important data, much of it the first of its kind.

I want to thank all the members of the NIF team from around the Laboratory and around the world for their extraordinarily hard work.

Over the next 30 years, NIF's projected lifetime, NIF will change. New uses will be found for it that we cannot dream of today. However, as NIF evolves, it will continue to successfully meet experimental challenges ◆

Getting 'Up Close' with NIF

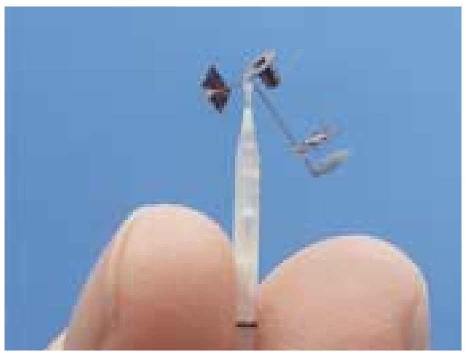
The National Ignition Facility is the flagship experimental facility of the Stockpile Stewardship Program. This special "Up Close" section of *Newsline* spotlights the progress on NIF and how NIF will be used to meet Laboratory missions. ◆

A look inside the cavernous 33-foot-diameter NIF target chamber as a target is being moved into position prior to an experimental shot.

The National Ignition Facility is here!

At long last, the laser beams at the National Ignition Facility (NIF) have begun to flash. And they are generating unprecedented levels of laser energy. Along with this major accomplishment comes a rush of interest from the scientific community where users are poised to exploit NIF's capabilities for stockpile stewardship, inertial fusion energy and basic and applied science.

Since breaking ground in May 1997, the NIF team has been striving for first light. Led by Project Manager Edward Moses and NIF Programs Associate Director George Miller, the team has delivered the first four of its 192 laser beams to targets in the 33-foot-diameter target chamber. The first scientific data arrived this summer. Along the way, the team has overcome many technical and management hurdles to make NIF a reality.



An example of a tiny NIF target

On the technical side, Moses likes to highlight six "miracles," the most challenging technologies that had to be solved. These include the high-gain, high-stability preamplifier system that injects laser pulses into the main laser; the amplifier system that increases the energy of the original pulse by a factor of a quadrillion; the high-quality laser glass used in the main amplifier system; the rapid-growth potassium dihydrogen phosphate (KDP) crystals used in the optical switches and for frequency conversion; the full-aperture adaptive optic mirrors; and the integrated computer control system that operates all of NIF.

With some of its first shots, NIF set world records for laser performance in the infrared, green and ultraviolet wavelengths. When this achievement is applied to all 192 beams, NIF's total energy can meet and surpass the originally specified energy requirements.

NIF is a contrast of the very large and the very small. The football-stadium-sized facility houses precision optical systems that are located to an accuracy of one quarter of a millimeter and aligned to point and focus the beams to a region less than the width of a hair. NIF contains the world's largest power conditioning system, storing up to about 400 million joules of electrical energy.

The laser system starts with a master oscillator "seed" pulse of about one billionth of a joule in energy. Then the system amplifies the light one quadrillion times to more than four million joules of infrared laser energy.

Inside the target chamber, NIF lasers can produce pressures reaching 100 billion atmospheres and temperatures of 100 million degrees, conditions that exist naturally only in the centers of stars or in nuclear weapons. With this unique capability, scientists can study high-energy-density physics for basic science and stockpile stewardship in a controlled laboratory setting.

In addition, NIF is capable of achieving fusion ignition and burn with energy gain, an important process that powers the stars and provides the immense explosive yields of nuclear weapons.

With a total budget of $3.448 billion, NIF is the largest single undertaking by the National Nuclear Security Administration. It's no surprise that a project of this magnitude presented management challenges all through its history. Today, NIF and LLNL senior managers can point to a continuous string of accomplishments and milestones that meet the schedule and budget approved by DOE and Congress in 2000.

Equally important has been the project's attention to safety. NIF has now completed more than 970 days without a lost workday injury.

As work on the laser system proceeds into 2008, everyone involved in NIF expects the project's many successes to continue. ◆

MISSION: The three important roles for NIF

The National Ignition Facility's 192 intense laser beams will be harnessed to create the extreme conditions that are key to fulfilling all three of NIF's primary missions: supporting the NNSA's Stockpile Stewardship Program for national security; performing research on inertial fusion energy, with its promise of limitless energy production; and opening new regimes of basic science.

For the Stockpile Stewardship Program, NIF's experimental capabilities are essential for providing a full understanding of the operation of modern nuclear weapons. NIF is thus an essential component of our nation's stockpile assessment and certification strategy.

With NIF, researchers will finally achieve not only fusion ignition and a self-sustaining burn, but also energy gain, two important milestones in the scientific pursuit of fusion energy as a source of electricity. NIF will be the first facility to demonstrate both phenomena in a laboratory setting.

NIF high-pressure and high-temperature experiments will also be important for astrophysics, hydrodynamics, material science, plasma physics and other areas of basic science. NIF will reveal the inner workings of stars, supernovae and other celestial bodies. Experiments on the interaction of lasers and plasmas will be important for the design of inertial confinement fusion targets. Still others will examine the strength of materials under extreme conditions.

Already, Laboratory scientists and engineers are looking into adding the capability of high-energy petawatt lasers for advanced diagnostic capability. NIF has been designed to evolve during the 30 years of its expected lifetime in response to emerging national needs. NIF will keep pace, always serving science in the national interest. ◆

National Security

NIF will provide valuable data for the NNSA Stockpile Stewardship Program.

As the world's largest laser system, NIF will be a unique facility, the only one in the Stockpile Stewardship Program that can study thermonuclear burn in the laboratory. NIF's controlled laboratory environment offers unprecedented experimental access to the physics of nuclear weapons.

Even before all of NIF's 192 beams are fully operational, its experiments will be able to investigate the physics associated with weapons physics.

"In effect, NIF will allow us to break apart the physics of a weapon and examine each of the processes in isolation," says George Miller, associate director for NIF Programs, and a major participant in the development of NNSA's Stockpile Stewardship Program.

"NIF will complement testing at other facilities by extending the ability of those experiments to investigate important areas of high-energy-density science directly related to the primaries and secondaries of nuclear weapons," Miller said.

Experiments on NIF support stockpile stewardship in three important ways, by:

- Examining the issues that can affect aging or refurbished weapons in the nuclear stockpile.
- Advancing critical elements of the underlying science of nuclear weapons that play an important role in validating advanced computer simulation codes.
- Attracting and training the exceptional scientific and technical talent required to sustain the Stockpile Stewardship Program over the long term.

NIF data will also help answer questions raised by planned and proposed Life Extension Programs, which ensure that our nuclear weapons remain reliable and able to perform their military functions well beyond their originally intended lifetimes. ◆

Fusion Energy

Power plants of the future may be based on fusion knowledge derived from NIF energy experiments.

Within the atoms of any element, smaller particles in the nucleus (neutrons and protons) are held together by binding energy. When lighter nuclei fuse together (nuclear fusion) or when heavier nuclei split apart (nuclear fission), the rearrangement of the particles releases large amounts of that binding energy.

The nuclear power plants scattered around the world today are all based on the fissioning, or splitting, of atoms to release energy for electricity. Fusion energy plants require much higher operating temperatures and are still in the experimental phase.

Researchers around the world have been striving to establish fusion energy as a source of electricity for 50 years. While a self-sustaining fusion burn has been achieved for brief periods under experimental conditions, the amount of energy that went in to creating it has exceeded the amount of energy it generated. In other words, there has been no energy gain.

Despite these difficulties, moving toward the establishment of commercial fusion energy power plants is a major goal of the Department of Energy. Fusion power plants would operate with lower levels of long-lived radioactive byproducts than fission plants. Fusion fuel can be obtained from water, in the form of deuterium and tritium, which are heavy isotopes of hydrogen. Furthermore, the energy released per unit of fuel is higher in a fusion plant.

Theory and experimental evidence agree that with NIF conditions are finally right for achieving both a self-sustaining fusion burn and energy gain. Creating inertial confinement fusion in the NIF target chamber will be a significant step toward reaching the goal of making fusion energy viable in commercial power plants. ◆

Basic Science

Researchers will be able to design experiments to model the interior pressures of stars and planets

With NIF, astrophysicists can study the materials that make up celestial bodies at extreme temperatures and pressures. These conditions are found in stars, such as our sun, in gaseous planets such as Jupiter and Saturn, as well as in massive dying stars and gamma ray bursts, one of the many mysteries of the cosmos.

"NIF will offer entirely new opportunities for pursuing experimental science under extreme conditions of temperature and density," says Bruce Remington, group leader in the High Energy Density Physics program. "The mechanisms that drive stars and other astrophysical phenomena such as supernovae, black holes and even planetary interiors are not well understood. For scientists to be able to construct accurate computer models requires a more complete understanding of the nature of dense plasmas than we have now."

Many NIF experiments will have more than one application. An examination of turbulence will apply to the mixing of materials in exploding supernovae as well as in exploding nuclear weapons. Warm dense matter, an energetic plasma whose density is almost that of a solid, is thought to exist in the centers of large planets such as Jupiter. Its properties are important not only to astrophysics but also to the production of inertially confined fusion reactions.

NIF will unlock other secrets of high-energy physics, too. The first experiments are demonstrating how NIF's laser beams interact with plasmas, as shown on page 6 of this insert. Directing NIF's lasers at materials to shock them will help to refine their equations of state or demonstrate how materials act at high pressures and densities.

Basic science in its many forms will reap huge benefits from NIF's unprecedented experimental capabilities. ◆

HOW IT WORKS: Tracking the beam

Each NIF beam begins with a nanojoule energy pulse from the master oscillator. This oscillator can create a variety of pulse shapes for different experiments, from complex, high-contrast, temporally shaped pulses for inertial confinement fusion implosions to high-energy, flat-in-time pulses for material science.

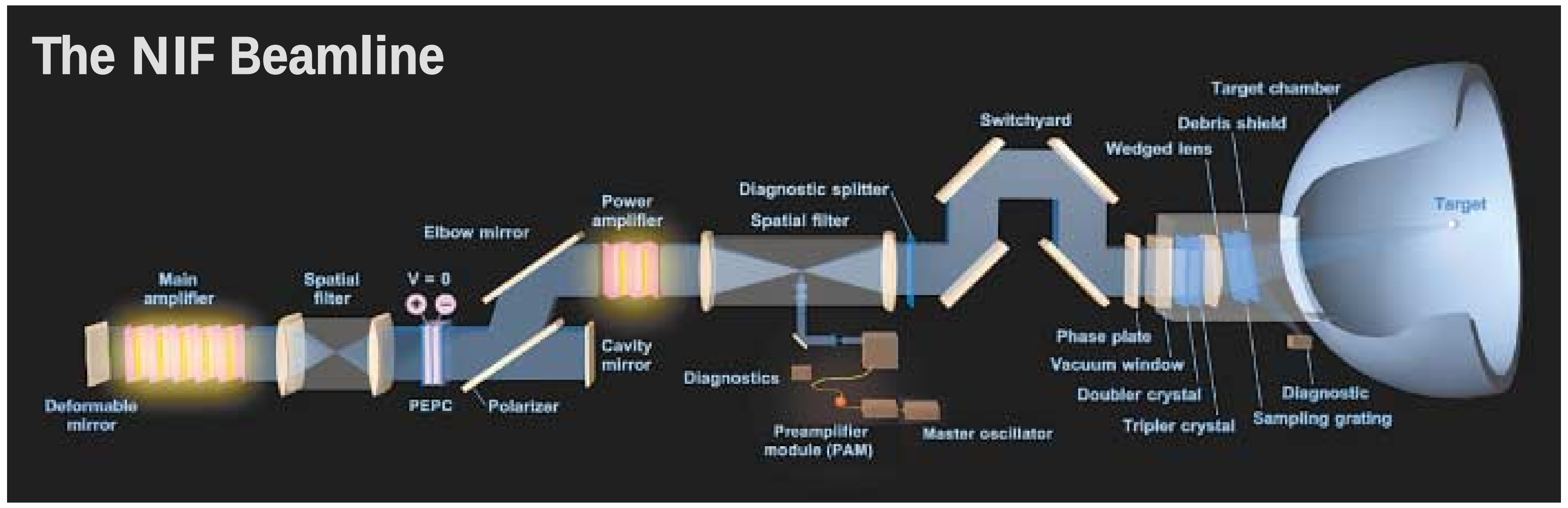
The initial pulse is transported to a preamplifier module (PAM) for amplification and spatial shaping. Each PAM first amplifies the pulse by a factor of ten billion using a diode-pumped, fiber laser system and then boosts the pulse once again by a factor of 20,000 by passing the beam four times through a neodymium-doped glass flashlamp-pumped amplifier. The beam's energy is now up to a few joules.

The laser beam next enters the large amplifier units — the power amplifier and the multi-pass main amplifier. These systems efficiently amplify the PAM pulse to the required energy and power, maintaining the input beam's spatial, spectral and temporal characteristics. After leaving the PAM, the beam passes through the power amplifier, four times through the main amplifier, and back through the power amplifier before continuing to the target chamber.

The amplifiers use approximately 3,000 neodymium-doped phosphate glass slabs. The slabs are surrounded by vertical arrays of nearly 7,000 two-meter-long flashlamps. Each flashlamp is driven by 30,000 joules of electrical energy from the power conditioning system, which consists of the highest energy array of electrical capacitors ever assembled. The intense white light from the flashlamps excites the neodymium atoms in the laser slabs to provide optical gain at the 1.06-micrometer (infrared) wavelength of the laser. Energy stored in the neodymium is released when the laser beam passes multiple times through each slab. The total amplification factor on NIF is more than a quadrillion.

A key beam line component is an optical switch called a Plasma-Electrode Pockels Cell (PEPC). When combined with a polarizer, the PEPC allows light to pass through or reflect off the polarizer. The PEPC traps the laser light between two mirrors as it makes four one-way passes through the main amplifier system before being switched out to continue through the power amplifier again.

NIF's target chamber includes a number of entry ports that allow "quads" of four laser beams to be focused to the center of the chamber through a final optics assembly. Its precision optics provide a variety of beam profiles on target. Potassium dihydrogen phosphate (KDP) and deuterated KDP plates convert infrared laser light into the ultraviolet wavelength, the final focus lens, and debris shields for each beam. ◆



All beams finally converge in the massive target chamber. Measuring 33 feet in diameter and weighing 1 million pounds, it was lowered into position on June 11, 1999, with a final accuracy of one quarter of a millimeter.

It was originally cast as an 18 7.5-ton, four-inch-thick flat plates in West Virginia, precisely shaped in France, and precision-trimmed and machined in Pennsylvania. The plates were then assembled in a temporary facility across the Inner Loop Road from the NIF building before installation by a heavy-duty crane imported for the occasion from the Nevada Test Site.

After assembly, 192 holes of various sizes were precisely located and bored into the four-inch-thick aluminum for laser beams, diagnostic instruments, targets and other equipment that will be placed in the chamber.

Laser beams are precisely aimed into the target chamber by special mirrors in two identical 10-story steel structures on either side of the target bay. Called switchyards, these structures are built to resist vibration and are firmly anchored to the building. They are among the stiffest structures of this size ever built.

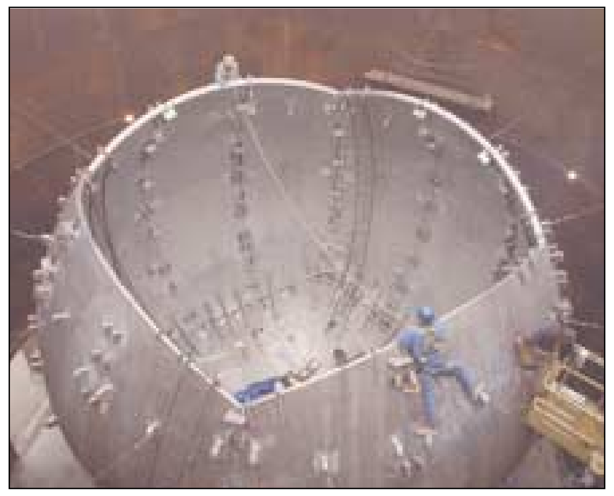
Once inside the target chamber, the laser beams zoom toward millimeter-sized targets precisely located at the center of the chamber by the target positioning system and the target alignment sensor positioner.

In ignition experiments for basic energy research and stockpile stewardship, a gold cylinder called a hohlraum will contain a tiny BB-sized fusion capsule filled with deuterium and tritium, two isotopes of hydrogen.

As the beams heat the hohlraum, it releases X-rays that rapidly ablate the surface of the capsule, which compresses the deuterium-tritium mixture to 20 times the density of lead, with temperatures reaching tens of millions of degrees. The isotopes fuse together and are converted into helium, expelling extra neutrons and large amounts of energy. The resulting energy is limited by the amount of fusion fuel in the tiny pellet and is therefore totally controllable.

Non-ignition experiments will use a variety of targets to derive a better understanding of material properties under extreme conditions. These targets can be as simple as flat foils or considerably more complex. By varying the shock strength of the laser pulse, scientists can obtain equation-of-state data that reveal how different materials perform under extreme conditions for stockpile stewardship and basic science. They can examine hydrodynamics, which is the behavior of fluids of unequal density as they mix.

NIF experiments will also use some of the beams to illuminate "backlighter" targets to generate an X-ray flash. This allows detailed X-ray photographs, or radiographs, of the interiors of targets as the experiments progress. ◆



The 33-foot-diameter NIF target chamber has changed dramatically since it was constructed in an adjacent structure, then lifted into position at one end of the building. Crews are now fitting the square tubes containing the laser beams to the final optics assemblies, which are already attached to the sphere.

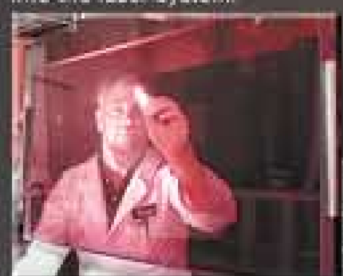
NATIONAL IGNITION FACILITY

7 A 360-degree panorama of the Class 100 clean room facility in the Optics Assembly Building.

6 The NIF Control Room controls all aspects of the laser system and target experiments.

5 At the center of the 33-foot-diameter target chamber, the 192 ultraviolet laser beams converge on the target.

1 The NIF laser contains more than 3000 pieces of amplifier glass. They are cleaned and assembled into modules before automated guided vehicles install them into the laser system.



2 The cable plant delivers electrical power to the flashlamps in the amplifier system.

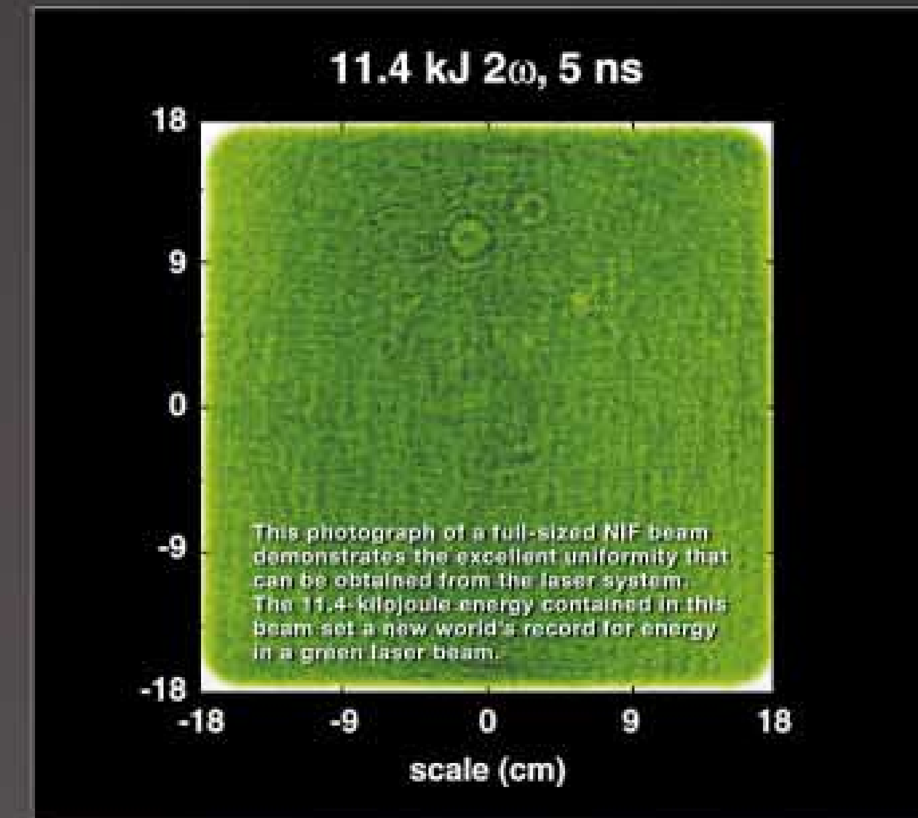
3 Beam tubes transport laser light to the target chamber.

4 Slices of giant crystals convert the infrared lasers to ultraviolet light before the beams enter the target chamber.

The National Ignition Facility

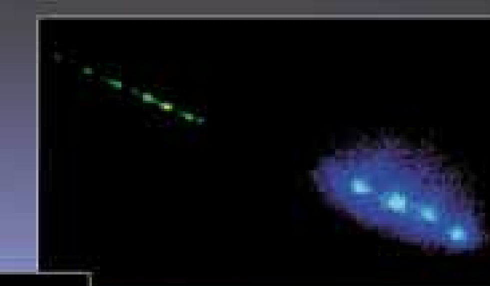
The NIF building complex was completed in September 2001. Spanning the length of two football fields, the facility will house 192 laser beams in two bays in precision-aligned and environmentally controlled conditions. The aerial photograph of NIF has been combined with a computer-generated model revealing one bay of the laser system. NIF delivered its first laser light to the target chamber on January 31, 2003, and will be completed with all 192 laser beams operational in 2008. You are invited to follow the progress of NIF on our web site http://www.llnl.gov/nif.

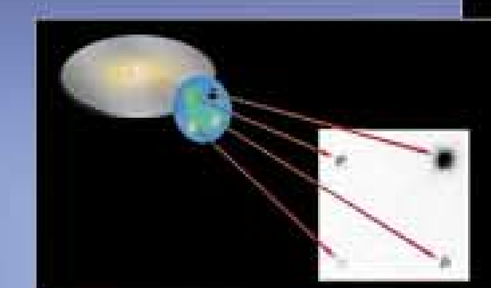
Early Experimental Results



This photograph of a full-sized NIF beam demonstrates the excellent uniformity that can be obtained from the laser system. The 11.4-kilojoule energy contained in this beam set a new world's record for energy in a green laser beam.

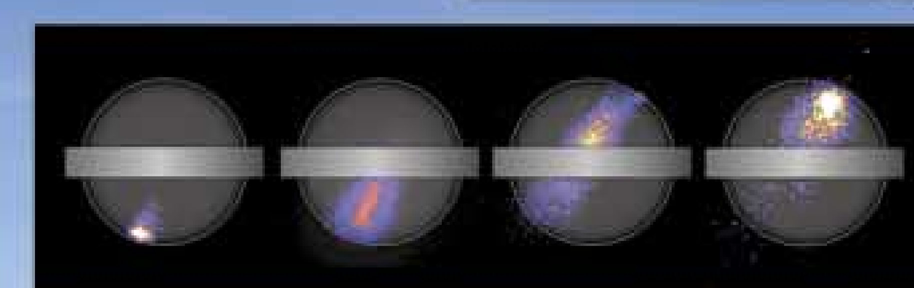
This is an optical photograph of four ultraviolet laser beams focused in a linear pattern on a simple metal foil target. The blue light emanates from the focused beam spots, and the green light is scattered light off the glass supporting stalk.





This is the first x-ray image ever obtained from a target in NIF. A single ultraviolet NIF beam was focused onto a gold-coated plastic foil at the center of the larger "puck." The x-rays emitted from the foil were imaged through titanium filters of four different thicknesses using a pin-hole camera, producing the four images on the left.

Laser-plasma interaction experiments use gas-filled targets to study fundamental plasma physics processes of importance to the inertial confinement fusion program. The photo on the right shows the millimeter-sized target – a spherical plastic shell mounted on a metal washer. The images below show the x-rays from the evolving plasma wave in the gas generated during laser illumination of the target.



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THE NATIONAL IGNITION FACILITY • SCIENCE IN THE NATIONAL INTEREST

BUILDING NIF: Keeping it clean

Although the National Ignition Facility looks nearly complete from the outside, inside the building workers are continuing to install the precision aligned and ultraclean enclosures that hold all the optical systems for each beamline. This beampath infrastructure has had to be kept pristine during all phases of fabrication and installation.

To connect the beam tubes along the 1,000-foot beampath to the target chamber, NIF engineers partnered with Jacobs Facilities Incorporated.

One of the most important technological developments arising from this partnership involved the use of temporary and portable cleanrooms during assembly of the beampath. The laser bays, 450 feet long and 100 feet wide, are too large to be placed under stringent cleanroom protocols.

Instead, low-cost, temporary cleanrooms were fabricated using scaffolds, plastic sheeting, and high-efficiency filter systems. These simple cleanrooms are significantly cheaper to construct than dedicated cleanrooms, resulting in a much reduced cost for NIF.

In these better-than-Class-100 cleanrooms — allowing fewer than 100 dust particles smaller than 0.5 micrometer in diameter per cubic foot of air — workers must wear full cleanroom suits.

The main laser bays are maintained under Class 100,000 cleanroom protocols. Under these conditions, workers are required to wear only hairnets and booties.

The ultimate test of these installation techniques began in 2002, when the first line replaceable units (LRUs) containing laser glass and flashlamps were robotically installed and removed multiple times to check that alignment and cleanliness requirements were being met.

After the successful completion of these tests, increasingly energetic flashlamp shots served to clean the beampath further before more than 120 LRUs were installed for NIF's first four beams.

"After nearly 140 full-system shots, no degradation of optics has been observed," says Ed Moses, NIF project manager. "This is a testament to the great work of our construction contractors and our quality control teams." ◆

A laser mirror is being inspected in the ultraclean Optics Assembly Building.

Laser Bay 2 where workers wear hairnets and booties.

CONTROL ROOM: Shooting targets

The National Ignition Facility control system brings together the very large and the very small of NIF, from keeping optical elements precisely aligned to fractions of the width of a human hair inside a stadium-sized building to finely orchestrating a sequence of events that take place hours, to the second before a shot, culminating in the billionths of a second laser pulses that themselves are in lock-step to better than a few trillionths of a second.

Controlling NIF from the macroscopic to the microscopic required the development of a completely new and fully integrated laser control system architecture on a scale never before attempted. NIF's integrated computer control system is one of the most complex control systems in operation today.

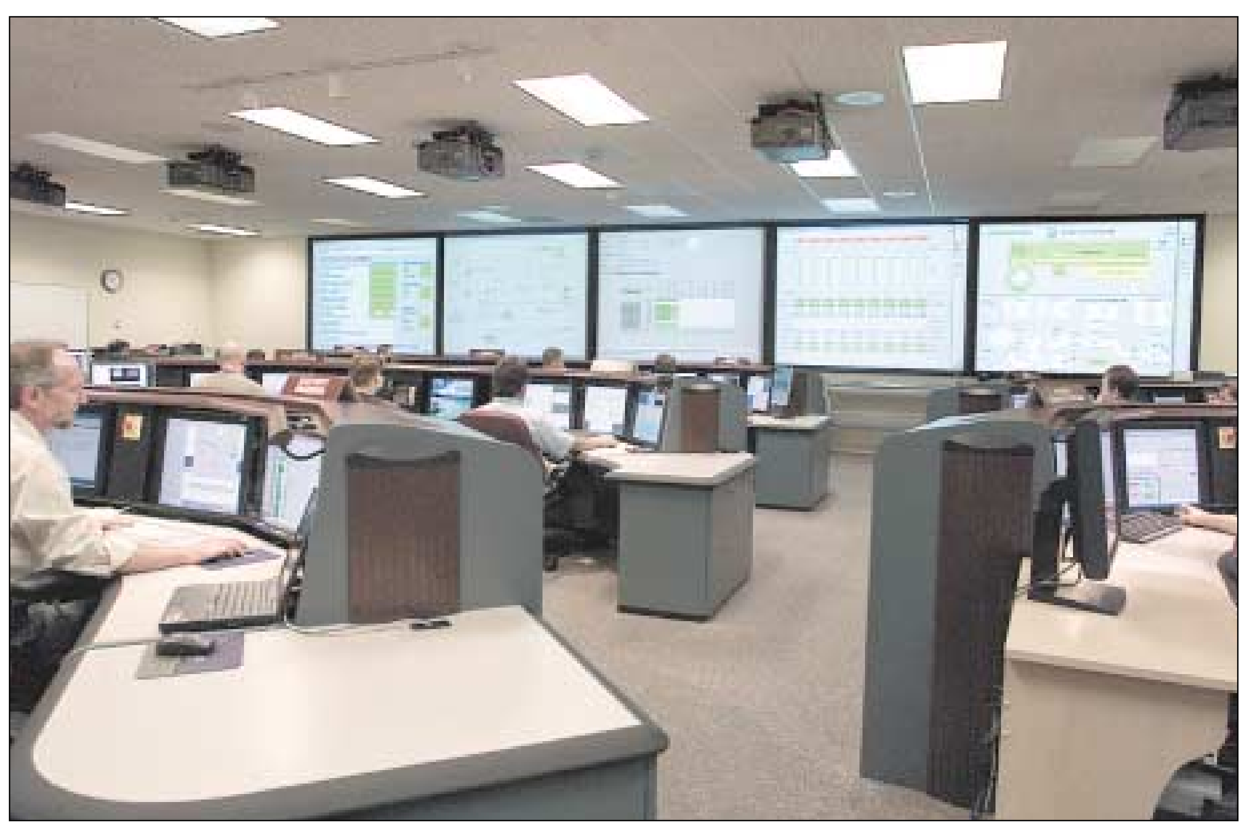
When fully installed, nearly one million lines of software will monitor and control every aspect of NIF's operation — from the moment the laser beam is first created to its final encounter with its target. NIF has more than 60,000 individual control "points" or computer-controlled elements that are used to set up, fire and process the information for each laser shot.

Says Paul VanArsdall, associate project manager for the control system: "We are currently implementing fully automated shot operations on the first four beams of NIF. Over the past few months we have successfully fired NIF as often as three time a day, demonstrating the ability to quickly cycle the entire laser system to meet our end goal of 700 shots a year on NIF."

During a NIF shot, the control room is abuzz with activity. Consoles are staffed by laser operations personnel and wall-sized displays show the latest information on shot set up and countdown.

NIF shots are conducted in a manner similar to a rocket launch. But there is no roar of rocket engines. The only visible manifestation of the shot, aside from fluctuating computer displays, is a sudden burst of light from flashlamps as they amplify the beams passing through the laser bay. The laser light itself is invisible to the human eye and so are the X-rays emanating from the vaporized target in the target chamber.

On a recent tour through NIF, a group of physics students from the UC at Santa Cruz was lucky enough to arrive at the control room about a minute prior to a shot. The group heartily joined in the countdown and was treated to a visual display of NIF beam profiles and data on the operator consoles a few seconds after the shot. The shot went off without a hitch thanks to the years of hard work by hundreds of software and control system engineers and technicians. ◆



The main control room at NIF.

OPTICS: From factory to beampath

Inspecting slabs of high quality, neodymium-doped phosphate laser glass.

After cutting and polishing, each laser glass slab is inspected.

The 192 beam lines require more than 7,500 large precision optics (laser glass, lenses, mirrors, windows, and crystals) and more than 26,000 small optical components.

While many of the National Ignition Facility optics will be used to steer the beams through the 1,000-foot-long beampath onto small targets, a number of the optics have other special roles. For example, the neodymium-doped phosphate laser glass is used to amplify laser light as it propagates through the beam lines. Also, specially grown crystals are used to switch the laser light in and out of NIF's multi-pass laser cavity as well as convert that laser light to the desired wavelength (color) needed to illuminate the target.

The laser glass is used in large flashlamp-driven amplifiers. In total, these amplifiers require more than 3,000 laser glass slabs. Each glass slab is about 0.8 meter long, 0.4 meter wide, and 4 centimeters thick.

Laboratory scientists joined forces with two optical glass producers — Schott Glass Technologies of Pennsylvania and Hoya Corp. USA of California — to develop an entirely new continuous-pour process to produce the high quality glass from which these laser glass slabs are fabricated.

The glass slabs are precision machined polished by Zygo Corp. of Connecticut using a novel grinding and polishing method that is much faster and more precise than any pre-NIF technologies.

The optics are then precision cleaned and coated with a special antireflection coating at a state-of-the-art optics processing facility at LLNL in Bldg. 391.

NIF optics manufacturing is now in full production. Prior to the start of production, LLNL scientists and engineers worked with many of the optics manufacturers to develop the manufacturing processes and build the necessary facilities and equipment.

"One of the great accomplishments of NIF is the tremendous advance in manufacturing of precision large optics. This advance has been made possible by LLNL's unique partnership with the optics industry," said Jack Campbell, NIF laser material and optics manager. "The innovative techniques used to make optics of the highest quality are a sign of a team dedicated to building the best system possible." ◆

Under cleanroom conditions, workers assemble a four-unit laser amplifier glass slab cassette.

A robotic transporter lifts and installs each cassette into place in the overhead beamline.

NIF CRYSTALS: Innovative rapid growth

Imagine taking a thumbnail-sized seed crystal, placing it in a special solution and winding up with a 700-pound crystal in 52 days. That's what a Livermore team set out to do more than three years ago when they were assigned the task of growing crystals large enough to be sliced into 40-centimeter-square plates for NIF optical switches and final optics.

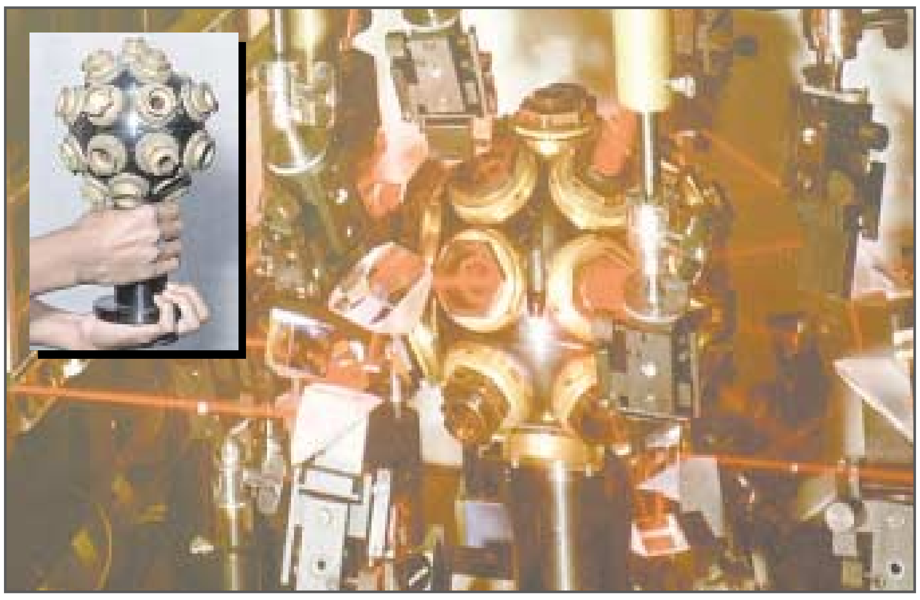
The crystals had to be grown fast enough to produce all the material that NIF would need. Traditional crystal-growing methods would have taken years to make enough.

Using a technique pioneered in Russia, the Lab's rapid-growth process begins with a synthetic seed crystal inside a 6-foot-high tank. The tank is filled with nearly a metric ton of supersaturated potassium dihydrogen phosphate (KDP) solution at 150 degrees Fahrenheit. The crystal rotates carefully on a turntable in the tank. The temperature is gradually decreased to maintain super-saturation as the growing crystal extracts salt from the solution.

The resulting crystals are large enough to allow the production of fewer crystals with a corresponding cost savings, while providing NIF with all the necessary KDP optics. ◆

Crystals grow up to 700 pounds in specially designed tanks. New techniques, refined at LLNL, shortened the growth process from two years to two months.

HISTORY: A growing laser capability



The "4 pi" laser system, dating from the mid-1960s, had 12 ruby laser beams arranged around a gas-filled target chamber only about 6 inches in diameter.

The one-beam Cyclops was completed in 1974. It served as a test bed for optical designs and as a prototype for the Shiva laser.

For most of the past three decades, the Laboratory has been home to the world's largest lasers. Former LLNL Director John Nuckolls has noted that the early decision to build solid-state lasers was key to Livermore's preeminence in laser science. The enthusiastic support of Laboratory management, Congress, the Atomic Energy Commission, and the Department of Energy was also critical to LLNL's success.

Since 1972, Livermore scientists have designed, built and operated a series of increasingly energetic and powerful solid-state systems. It all began with the "4 pi" system and continued with Janus, Cyclops, Argus, Shiva, Novette, Nova, Petawatt and Beamlet.

The National Ignition Facility is continuing that proud tradition. When the last of its 192 beams are installed in 2008, NIF will offer unique capabilities, including the most energy of any laser facility in the world.

With its ability to provide a variety of laser pulse shapes and lengths, including the proposed ultrashort, petawatt pulses, NIF will also offer more power than any other laser facility.

"The National Ignition Facility will be about 20 times more powerful than the Nova laser and will deliver about 60 times more energy," said John Lindl, Livermore's scientific director for inertial confinement fusion.

When Nova operated with ultraviolet light, it produced 30 kilojoules of energy and 25 terawatts of power. In contrast, the 192-beam NIF will generate 1.8 megajoules and 500 terawatts.

LLNL technology has supplied the seed for other large glass laser efforts in the United States, including the Omega laser at the University of Rochester in New York and the Beamlet laser now at Sandia National Laboratory. Lasers in Japan, France, the United Kingdom, Germany, and other countries around the world also use LLNL technology.

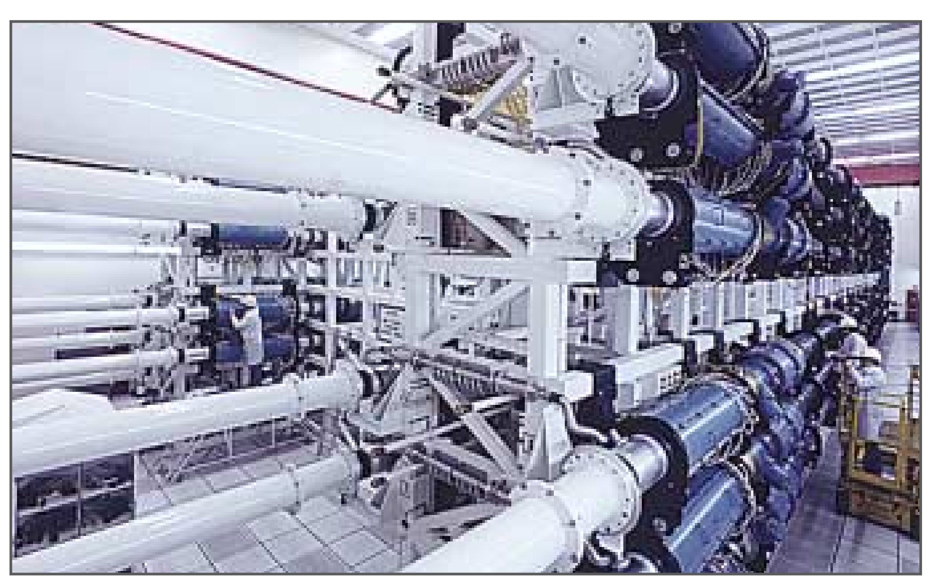
Craig Wuest, NIF assistant associate director, sees the NIF laser as a "great opportunity" to combine high energy with high power.

"NIF will open new fields of research or expanded capabilities for studying materials science, nuclear physics, astrophysics and weapons physics," Wuest says. ◆

In 1974, the Janus laser conducted initial fusion experiments and demonstrated the thermonuclear reaction in laser-imploded deuterium–tritium capsules.

In 1976, the two beams of the Argus laser system filled an entire room.

Nova, completed in 1984, featured 10 beams converging in a 15-foot-diameter target chamber. In 1996, one arm of Nova was reconfigured as a petawatt laser.



The 20-beam Shiva became the world's most powerful laser in 1977, delivering 10.2 kilojoules of energy in less than a billionth of a second.